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DEVELOPMENT AND APPLICATION OF OPERATIONAL TECHNIQUES FOR THE INVENTORY AND MONITORING OF RESOURCES AND USES FOR THE TEXAS COASTAL ZONE

Peggy Harwood — The General Land Office
1700 North Congress
Austin, Texas 78701

Robert Finley — Bureau of Economic Geology
The University of Texas at Austin
Austin, Texas 78712

Samuel McCulloch
David Murphy
Bill Hupp — Texas Water Development Board
Austin, Texas 78701

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16. Abstract

The image interpretation mapping techniques have been successfully applied to test site 5, an area with a semi-arid climate and consequently a very different coastal environment than the previously-studied test sites. As a result, the land cover/land use classification developed for this investigation required further modification to make it applicable to the entire Texas coast.

A new program, HGROUP, added to the ADP classification schedule provides a convenient method for examining the spectral similarity between classes. This capability greatly simplifies the task of combining 25-30 unsupervised subclasses into about 15 major classes that approximately correspond to the land use/land cover classification scheme developed for this investigation.

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1.0 INTRODUCTION

1.1 Scope and Purpose of Report

This progress report covers activities during the fourth quarter, March 25, 1976 through May 25, 1976, for LANDSAT Investigation #23790. This investigation is funded for 19 months to develop techniques in Texas state agencies for using LANDSAT data to inventory and monitor coastal resources and uses. The General Land Office (GLO) is the Texas agency coordinating this investigation. Other participating agencies are the Bureau of Economic Geology (BEG), Texas Water Development Board (TWDB), and Texas Parks and Wildlife Department (TPWD).

1.2 Summary of Work Performed

During the fourth reporting period, activities centered around completing at least one scene in test sites 2 and 5 in humid and semi-arid zones of the Texas coast, respectively. In addition, plans were completed for the summer "test" of using image interpretation and ADP techniques to address General Land Office coastal management concerns, and for collecting data for the cost-savings analysis.

Specific accomplishments include: 1) detailed analysis of image interpretation results from test sites 2 and 5, 2) refinement of the land use/land cover classification scheme developed for this investigation and correlation of this classification with the U.S.G.S. system, 3) introduction of a new program (HGROUP) to the ADP classification schedule, and 4) preliminary development of a program to extract boundaries from ADP classification results.

2.0 PROBLEMS

Anticipated examination of the effect of seasonal and other changes in 2 LANDSAT scenes for each test site (2, 3, and 5) has been delayed until late Summer or Fall because: 1) additional scenes for sites 2 and 5 have not been completed due to anticipated additional technique development by June 1, 1976, when the analysis of site 4 is scheduled to begin, and 2) there was a delay in receiving field support data for sites 2 and 5 from Texas Parks and Wildlife Department.

3.0 ACCOMPLISHMENTS

3.1 Data Acquisition

The current status of LANDSAT data acquisition to support this investigation is reflected in Appendix A. The CCT's ordered for Test Sites 4 and 5 were received. Complete packages of imagery and digital data are now available as follows: Test Site 2: 3 scenes (1 summer, 1 winter, 1 spring); Test Site 3: 4 scenes (1 summer, 2 winter, 1 spring); Test Site 4: 4 scenes (1 summer, 3 winter); Test Site 5: 3 scenes (1 summer, 2 winter). As indicated, these data sets provide some seasonal variations within each test site. In addition, for Test Sites 3, 4, and 5, the data sets within the winter season are separated by one to four years so that longer term trends in land use and land cover can be analyzed.

3.2 Examination of Test Site 2 (West Galveston Bay Area)

3.2.1 Image Interpretation Results of Site 2

Image interpretation of LANDSAT film transparencies reveals the complex active and abandoned natural drainage patterns, as well as dredged channels and the details of natural and jettied inlets within this coastal segment. San Luis Pass (Figure 1), an unmodified tidal inlet, is spanned by a highway bridge which is detectable with LANDSAT data. Extensive topographically low marshes just inside the pass were correctly identified and contain an abundance of *Spartina alterniflora*. Islands of less water content and higher reflectance vegetation surrounded by the low marsh were classified as high marsh, a decision which appears valid after examination of 1:40,000 color-infrared aerial photography (NASA Mission 325.)

However, some initial errors in classification also occurred, and three examples are illustrated by Figure 1. A barely emergent marshy island (A, Figure 1) was mapped as highly turbid-shallow water. Where beach width decreases below about 80 m. (B, Figure 1) the beach, breaking waves, and the nearshore zone of turbid water appear as a zone of highly turbid or shallow water adjacent to the vegetated barrier flat. A strip of high-reflectance sand (C, Figure 1) is mapped as undifferentiated barren rather than dredge spoil because the adjacent channel, about 50 m. in width, cannot be distinguished from the surrounding wet low marsh.

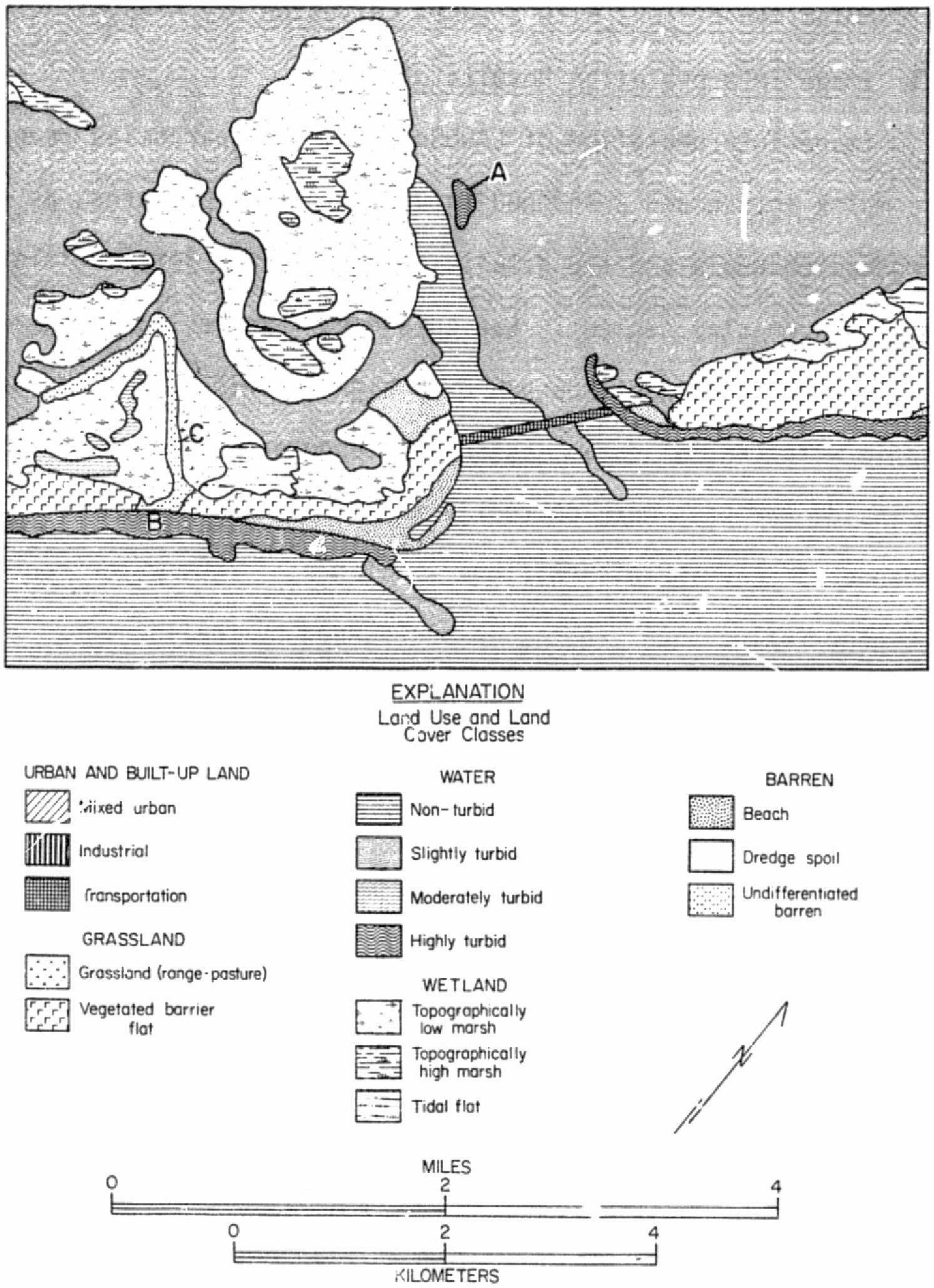

Figure 1. San Luis Pass area, test site 2, with classified land and water units delineated from LANDSAT scene 1289-16261, 8 May 1973. Lettered locations are explained in text.

The Freeport area (Figure 2) includes a major industrial-port complex nearly 3 km. in length and width, the urban areas of Freeport (A, Figure 2) and Surfside (B, Figure 2), and urban strip development (C, Figure 2) along State Route 332. This road leads northwest from Surfside but is not detectable where it crosses the low marshes landward of that city until the roadside development begins. At locality D (Figure 2), development becomes less continuous, but a string of individual industrial sites is a clue to the highway's location. On LANDSAT false-color composite transparencies, industrial sites are recognizable by: (1) the high-reflectance white to bluish-white tones caused by metal structures and the use of shell and sand fill, (2) the presence of holding ponds for liquids, and (3) distinguishable roads or dredged channels which lead to the site. Use of the first criteria alone can be misleading; at E (Figure 2) a rectangular area covered by barren dredge spoil approximately 160 by 400 m. in size was misinterpreted as an industrial location.

A detectable change in marsh type was mapped across a road (F, Figure 2) which, when checked in the field, was found to follow the crest of a hurricane-surge protection dike at an elevation of 4.9 m. (16 ft.). Natural species zonation within saline marshes is related to gradual elevation changes, with less salt-tolerant species at greater elevations above mean sea level. In this instance, the dike (F, Figure 2) separates saline from brackish- to fresh-water marshes over an extremely short horizontal distance.

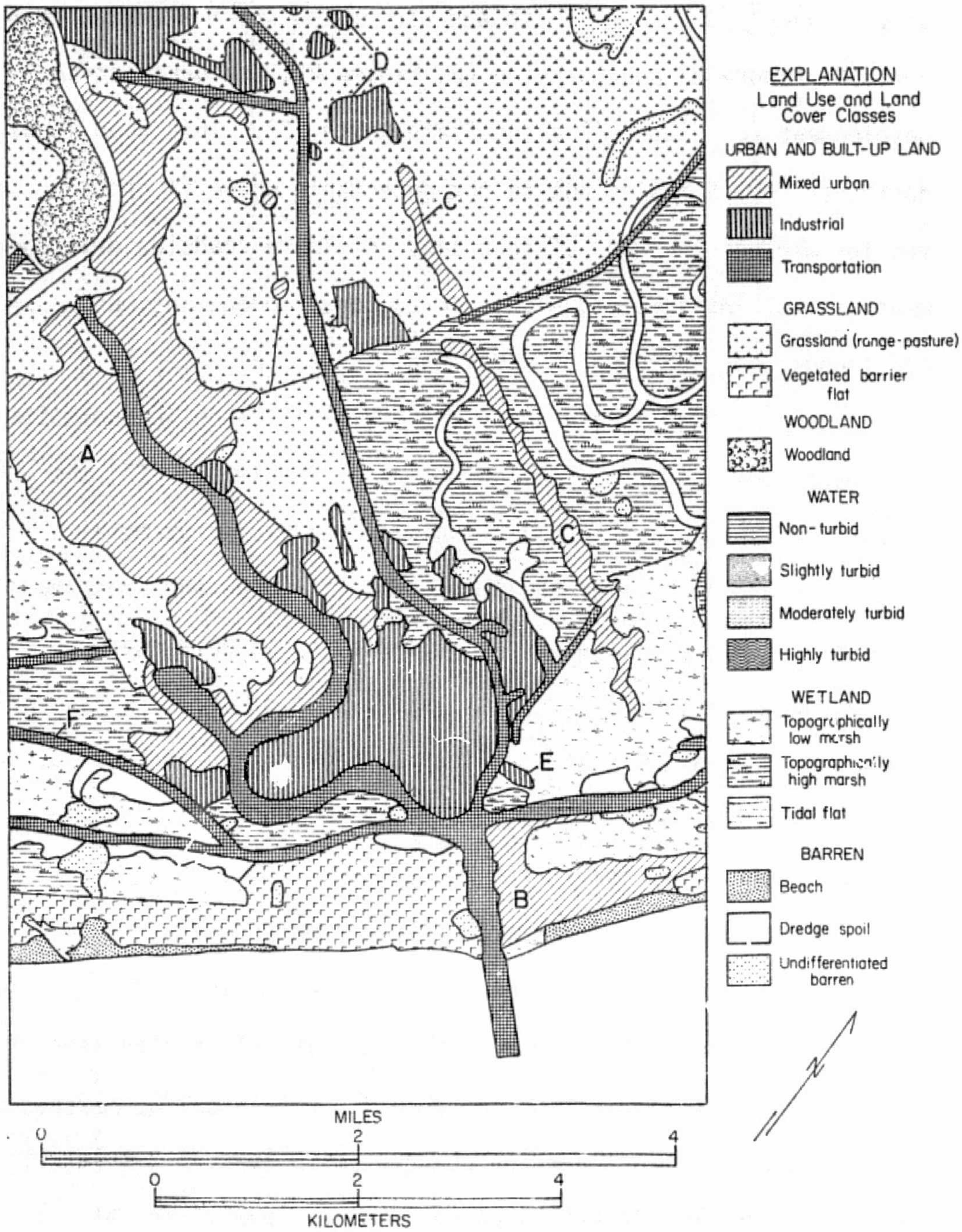

Figure 2. Freeport area, test site 2, with water units unclassified except for transportation (dredged canals or maintained river channel), delineated from LANDSAT scene 1289-16261, 8 May 1973. Lettered locations are explained in text.

Spartina alterniflora and *Batis maritima* are abundant seaward of the dike, along with a relatively greater area of open water, while *Spartina spartinae*, *Distichlis spicata*, and some *Scirpus* spp. (bulrush) are found on the landward side. The false-color composite response of the latter area is dull red to blackish-red while the former is bluish black with faint reddish-black patches.

3.2.2 Preliminary ADP Classification of Site 2

Preliminary registered classification maps for the 8 May 1973 scene (1289-16261) of Test Site 2 were completed during this reporting period. Because of the size and shape of the test area (7 quadrangle sheets arranged stepwise along the coast), each of the DAM, ELLTAB, CLASSIFY, and REGISTRATION steps required four runs to complete all 7 maps. This scene contains an exceptionally wide range of spectral levels, including particularly high reflectance areas, compared to those scenes previously studied.

To improve the classification on this scene, the sample size for establishing the ISOCLS statistics was increased in some areas. After considerable experimentation, the parameters used were: 1) maximum number of classes:40, 2) maximum number of points per cluster:20, 3) maximum standard deviation:3.0, 4) minimum cluster separation:2.0, 5) maximum iterations:10. After refinement of several clusters to reduce the standard deviations to acceptable limits, 40 subclasses were retained. Due to limitations in the allowable size of the ELLTAB Table, the classification

was handled in tow groups of 25 and 15 subclasses respectively. The two groups will be consolidated manually to arrive at a single classification map for correlation with image interpretation results.

After initial comparisons of the classification map with photo graphy (NASA Mission 300) and in conjunction with results of the HGROUP analysis (Section 3.5), the number of classes was reduced to 17.

3.3 Examination of Test Site 5 (Southern Laguna Madre Area)

3.3.1 Preliminary Description for Site 5

In the vicinity of South Padre Island a pronounced deficit in precipitation leads to active aeolian transport and only sparse barrier island vegetation. Blowouts are common and storm channels bring wash-over deposits to Laguna Madre. Broad tidal flats have been formed by wind transport of sediment derived from the over-wash deposits (McGowan and Scott, 1975). Algal mats are present on parts of the wind-tide dominated flats; subaqueous vegetation (seagrass beds) occur within the lagoon. Marshes similar to those found in Sites 2 and 3 are scarce. Low areas along the lagoon margin support saline grasslands consisting primarily of *Batis maritima*, *Monanthochloë littoralis* and *Borrichia frutescens* (sea oxeye), while at greater elevations and in less saline soils (Johnston, 1955) *Spartina spartinae* is found. The fluvial-deltaic sands and muds of the Modern-Holocene Rio Grande delta system supports the culti vation of citrus, vegetables, grain sorghum and other crops. The Brownsville Ship Channel leads to shipping facilities and shrimp docks at the port of Brownsville.

3.3.2 Image Interpretation Results for Site 5

Test Site 5 shows greater complexity (Figure 3) than the other test sites--especially evident in the inactive Modern-Holocene delta plains between the Rio Grande and the Brownsville Ship Channel and north of the Arroyo Colorado. The latter area is a complex of channels, tidal flats, subaqueous grass flats, algal mats, and undifferentiated barren substrate. The rectilinear boundaries in the region south of the Arroyo Colorado define cropland, seen on LANDSAT data as the gray of barren muddy fields, set within the dull brownish red of saline grasslands and the white to blue-white of undifferentiated barren clay-sand substrate.

The city of Port Isabel (A, Figure 4) is detectable with LANDSAT data, as are the two causeways leading across Laguna Madre to South Padre Island. The lawns and trees of the city interspersed with paved roads and urban structures give a pebbly, dull red and white pattern which, especially when seen with transportation features, helps identify urban complexes. Urban development on Padre Island, however, is not detectable because: (1) many streets are simply cleared areas of loose sand, (2) lawns and planted trees characteristic of developed areas are not present, and (3) structures immediately adjacent to the beach and within the foredune area are masked by the high reflectance of the barren sands. These residential and commercial areas therefore resemble the surrounding natural environment of barrier flat vegetation, tidal flat, and bare sand. A housing development consisting of dredged channels and spoil islands is mapped as tidal flat (B, Figure 4) since both environments appear simply as wet sandy sub-

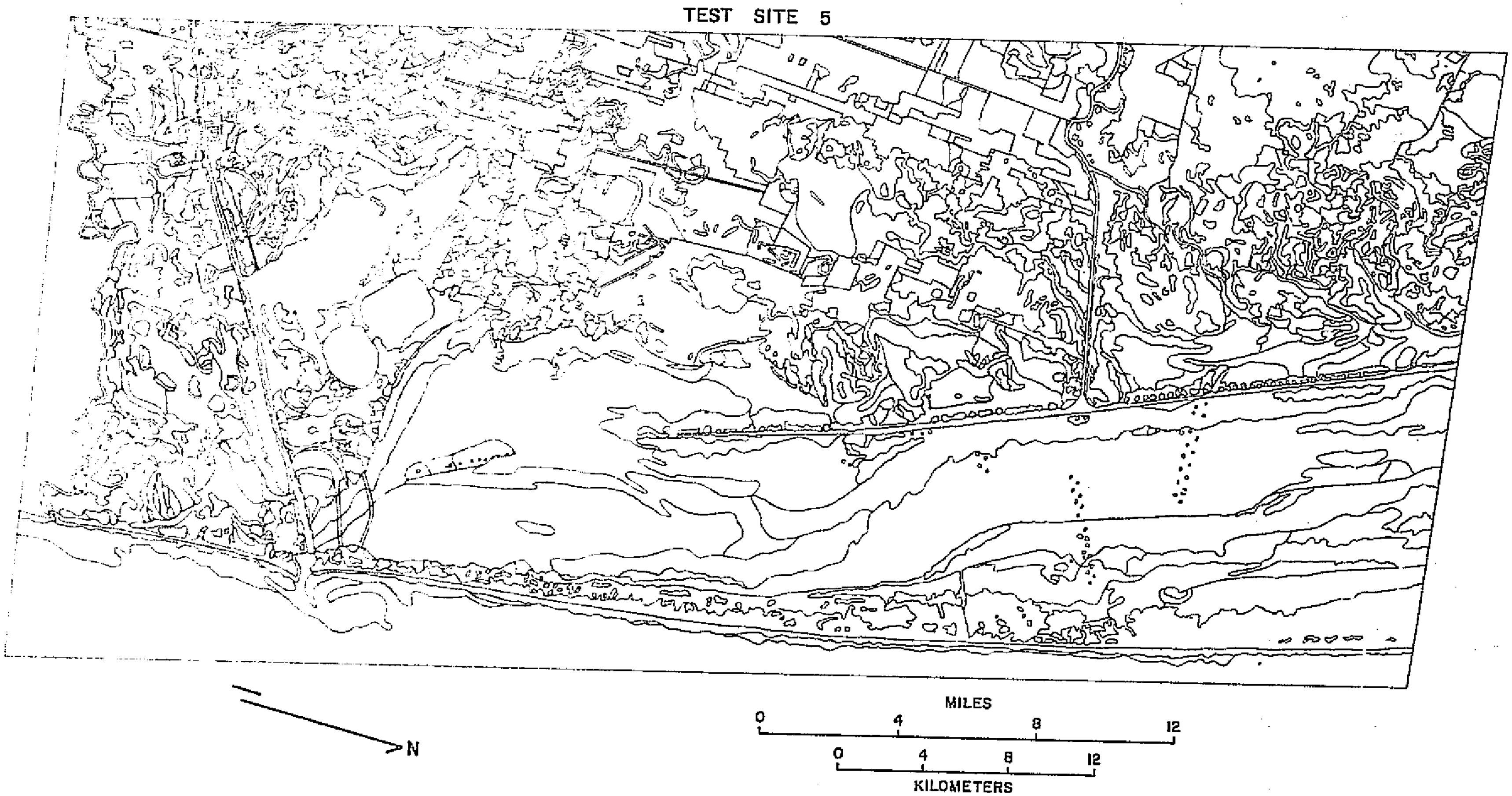

Figure 3. Unclassified line boundary map of test site 5 derived from LANDSAT scene 2034-16205, 25 February 1975.

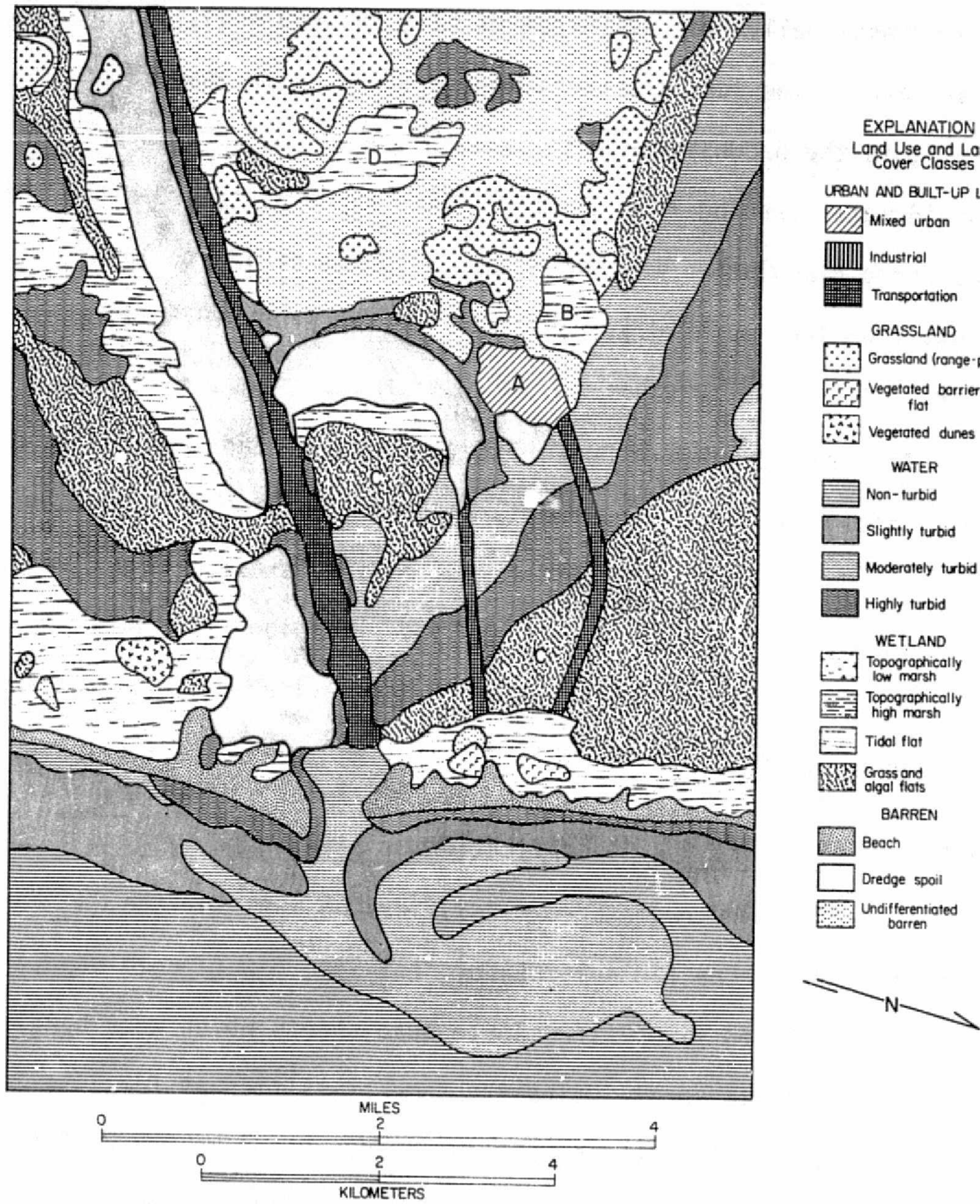

Figure 4. Brazos Santiago Pass area, test site 5, with classified land and water units (scene 2034-16205), lettered features are explained in text.

strate when individual channels cannot be detected.

Also within the Brazos Santiago Pass area are subaqueous grass flats (C, Figure 4), barren sandflats (D, Figure 4) which are occassionally flooded (Groat et al., in progress), and saline grasslands. The long transportation feature, with associated dredge spoil, is the Brownsville Ship Channel. Note that the moderately turbid water issuing from the tidal pass turns northward since the nearshore circulation was under the influence of 12- to 16-knot winds from the south (U.S. Department of Commerce, 1975) at the time of satellite passage.

As a result of work on this test site the land use/land cover classification scheme required further modification. The system shown in Table 1 is applicable to the entire Texas Coast and will be used during the remainder of the investigation. The numbers on the classification scheme refer to the revised U.S.G.S. system by Anderson, et al. (1976).

3.3.3 Preliminary ADP Classification of Site 5

Preliminary registered classification maps for the 25 February 1975 scene (2034-16205) of Test Site 5 were completed. The area included five 7 1/2 minute quad sheets which were handled as three separate runs. Using the same statistics as for Site 2 (Section 3.2.2), 25 classes were obtained. Based on the HGROUP analysis (Section 3.5), these were reduced to 17 classes. Maps showing both groupings were produced to be verified with aerial photography and maps of the Brownsville-Harlingen Area (Groat, et al., in progress), and also in later correlation with the image interpretation results.

Table 1.

LAND COVER AND LAND USE CLASSIFICATION
FOR USE WITH UNENHANCED LANDSAT DATA
IN THE TEXAS COASTAL ZONE

1	Urban or Built-up Land	U-Mixed urban (16) Ui-Industrial (13) Ut-Transportation (14) Ue-Extractive-hydrocarbons (131)
2	Agricultural Land	A-Cropland (21)
3	Grassland/Rangeland	G-Range-pasture (31) Gd-Vegetated dunes (311) Gb-Vegetated barrier flat (312) Gbr-Brushland (32)
4	Forest Land	WO-Woodland or chaparral (43)
5	Water (Level II omitted)	WA-Non-turbid (501) WAst-Slightly turbid (502) WAmt-Moderately turbid (503) WAt-Highly turbid/very shallow (504)
6	Wetland	Wlm-Topographically low marsh (621) Whm-Topographically high marsh (622) Wtf-Tidal flat (623) Wga-Seagrasses and algal flats (624) Ws-Vegetated dredge spoil (625)
7	Barren Land	B-Beaches (72) Bd-Dunes (731) Bds-Dredge spoil-barren (732) Bu-Undifferentiated barren land (77)

Numbers refer to system in Anderson, et al., 1976, U.S.G.S. Professional Paper 964. Two digit numbers identify Level II categories equivalent to U.S.G.S. Level II categories, although the descriptive terms may vary. Three digit numbers identify Level III categories.

3.4 Preliminary Evaluation of Techniques for Analysis of LANDSAT Data

Results of interpreting LANDSAT images of the Coastal Zone indicate that a substantial degree of success can be achieved in mapping land cover/land use from LANDSAT film products. A knowledge of coastal geologic processes and biologic assemblages is essential to this process because it enables the human interpreter to use much more than just reflectance in delineating coastal features. The shape of an object, its internal texture, and its characteristic position with respect to adjoining environmental units can supercede reflectance as the basis for making classification decisions. Perhaps because LANDSAT data originate in a digital format and are readily processed by machine, these aspects of imagery interpretation have received less attention than they certainly warrant.

Reflectance alone, seen as the color tones of the false-color composite or the gray tones of a single-band image, is not absolute for identifying each type of land cover and land use. The growth phase of the vegetation, recent weather conditions, atmospheric conditions at the time of image acquisition, and tide level are factors which must be taken into account in interpreting reflectance in a LANDSAT scene of the coastal region. The interpreter using standard LANDSAT products therefore must rely on a familiarity with the coastal environments in order to compensate for the limit of resolution of about 80 m. and the 1:1,000,000 scale of the imagery.

Preliminary results of classifying LANDSAT tapes using unsupervised automatic data processing (ADP) techniques indicate that some classes of similar reflectance, such as beach, barren spoil and some urban/industrial, also can be discriminated only by a human interpreter using supportive information. Advantages of ADP classification maps include 1) a large-scale display (1:24,000), when needed, 2) registration to U.S.G.S. 7 1/2 minute topographic maps with a RMS of 80-100 m., and 3) the use of statistical techniques to automatically reduce the volume of data to produce a map with 15 to 20 spectral classes.

3.5 Changes in ADP Techniques

During this quarter, several ADP features have been added or modified to enhance the accuracy or speed of the classification process or display of the classified results.

A very useful program, HGROUP, was acquired from the Regional Applications Project staff at NASA/JSC (Appendix B). When Classifying a LANDSAT scene for this investigation, interest is usually in a small number of basic catagories; e.g., water, wetlands, rangeland, urban, agricultural land, woodlands, and barren land. Even allowing subgroups of interest within some of these basic categories, the result would rarely be more than about 15 classes on one map area. However, the use of ISOCLS clustering on a LANDSAT scene usually produces upwards of 25 to 35 subclasses. One thus needs a method of combining many of these subclasses to reduce the number of major classes. This often proves to be a difficult and tedious task.

HGROUP is a valuable aid in this endeavor. Using a set of class means from ISOCLS that have been normalized, HGROUP performs a stepwise combining of classes. At each step, HGROUP combines the two classes that have the closest set of means. After combining two classes, a single set of means is generated for the combined class. The program continues combining classes until only 2 classes remain. With the help of a cumulative error function generated at each step, HGROUP can be used to combine the original set of subclasses into the final set of classes of interest.

Also, during this quarter, a program was written to extract boundaries from classified data (Appendix C). The boundaries are extracted in the form of chains of points which can be utilized by the Geographic Information System (GIS) now in development as part of the Texas Natural Resources Information System. Bourdary extraction enables the GIS to produce pen plots at a smaller scale than 1:24,000 from the LANDSAT boundary files, without the loss of information that occurs in line printer plots when lines and samples are dropped. At this time, polygons must be manually identified and labled, a time consuming task. Further capabilities (such as semi-automatic editing, polygon shading, area calculations, and overlaying of other base files) will become available as the GIS development progresses.

Another program being written is one to help clean up "noise" in the classified data. This is being accomplished by changing the classification of a pixel to reflect that of its neighboring

pixels. The result should lead to more homogeneous areas in the final map.

A program now in the design stage will use elements from the DAM package to perform simultaneous registration of two LANDSAT classification files of the same area (two different dates). As a matching pair of scan lines are being registered, they will be compared pixel by pixel for change. Only those pixels that have changed will be printed, thus giving a map displaying change between the two dates.

After consulting with Regional Applications Project staff at NASA/JSC, the methods of picking control points has been altered. It was pointed out that picking all the control points within the topographic quadrangles to be classified would not produce registration for that area as accurately as using control points from the entire scene or at least from one entire CCT. The entire scene will be used in the future wherever possible.

The LANDSAT ADP classification schedule was further refined to reflect addition of the HGROUP step and several minor changes in procedure which have evolved during the work on test sites 2 and 5. This new schedule, shown in Table 2, will be used to support the cost analysis of work performed on site 4 by reference to the step number when recording time and equipment utilization.

Table 2.

LANDSAT Task 2. Information Extraction: ADP Steps

Scene ID:

Test Site:

Description:

1. Select LANDSAT scene and determine data tapes ID number.
2. Examine available imagery.
3. Merge data tapes or duplicate tapes if necessary.
4. Estimate scan line and sample numbers for the areas of interest.
5. Generate grayscale maps of the area. (GRAYMAP/PICOUT)
6. Obtain meteorological data
7. Participate in orientation field trip.
8. Establish control network (COEF)
9. Classify water using DAM.
10. Cluster all training areas within the scene (ISOCLS).
11. Examine class statistics.
12. Refine a training class if indicated by step 10.
13. Use class statistics to build the look-up table (ELLTAB TABLE).
14. Combine subclasses for display purposes (HGROUP).
15. Classify the area (ELLTAB CLASSIFY).
16. Register and display the classified results (REGISTER).
17. Outline or color code homogeneous areas.
18. Examine the classification map.
19. Stop if satisfied with the results.
20. Retrain on unclassified or poorly separated areas (ISOCLS).
21. Go to step 12.

3.6 Summary of Accomplishments to Date

As a consequence of the current LANDSAT project activities, certain results have been developed which appear significant.

1) A land use/land cover classification scheme, that is representative of our investigation priorities, and applicable to the entire Texas Coast, has been developed which can be supported by LANDSAT interpretation. This scheme appears adequately detailed for use in coastal applications of several agencies.

2) An update of the Bureau of Economic Geology's Environmental Geologic Atlas of the Texas Coastal Zone (Brown, project coordinator) has been completed, using (February 1975 NASA photography (Mission 300), to provide a base map of the Coastal Zone features being studied with LANDSAT data.

3) Systematic procedures have been identified and developed for the interpretation of LANDSAT imagery according to the classification scheme. These image interpretation procedures can be used to generate a land use/land cover map of the coastal zone using conventional image interpretation and cartographic techniques, from which certain changes could be identified and evaluated for impact on the management of Coastal Public Lands.

4) Automatic data processing (ADP) procedures have been implemented for the generation of computer classification maps, that are scaled and registered to 1:24,000 U.S.G.S. topographic quadrangle maps.

5) During this summer, information needs of the General Land Office in a specific coastal area will be evaluated with respect to the LANDSAT classification products developed. It is anticipated that LANDSAT products could play a significant supportive role in the GLO decision-making processes related to the management of the States' interest in the coastal public lands.

In summary, specific procedures have been developed for manual interpretation and computer processing of LANDSAT data according to a classification scheme which is relevant to Texas Coastal Public Lands management. Also, it appears feasible that an ongoing program, applying these procedures, could be established to produce a coastal land use/land cover map, on demand, to planning and management activities in the General Land Office and other Texas agencies.

3.7 Program for Next Reporting Interval

During the interval June-August 1976, a test of procedures developed for image interpretation and ADP classification of LANDSAT data will be conducted in site 4, the Harbor Island area near Corpus Christi Bay, Texas. Four LANDSAT scenes will be analyzed for site 4

with the following dates: 2/25/75 (scene 1), 2/2/76 (scene 2), 7/10/75 (scene 3) and 12/16/72 (scene 4). Three scenes are winter scenes because cloud cover, obscuring part of test site 4, occurred on most scenes collected during the warmer seasons. The winter scenes will be used to investigate changes in land use/land cover that might have resulted from construction along the bay margins and dredging of ship channels between 1972 and 1976. The summer scene will be used to compare differences in classification results between summer and winter scenes.

A tentative schedule for this site 4 test is shown in Table 3. Task codes listed for ADP and II refer to steps on the LANDSAT ADP Classification Schedule (Jones, et al., March 1976, Table 2, p. 22) and the Schedule for Image Interpretation Analysis (Ibid, Table 3, p. 24). Estimates for completion of various tasks were provided by BEG and TWDB/TNRIS staff from experience gained from previous analyses for sites 2, 3, and 5, and are tentative depending on unforseen delays. The last two tasks on the schedule will follow completion of the image interpretation and ADP analyses, in September and October. The analysis of problems/information of interest to the GLO will begin when at least two scenes are completed for ADP and image interpretation. Special interests for the GLO include the following topics:

a) What is the area of inundation of tidal flats, marshes at different water stages? - such as water/land maps for each scene compared to one or more classification maps.

Table 3. Summer Schedule (Site 4 Test)

*field trip

Task Code	Task	June 1-4	7-11	14-18	21-25	28-2	July 5-9	12-16	19-23	26-30	August 2-6	9-13	16-20	23-27
II 1,2	Preparation for site analysis (including preliminary field trip)													
II 3	Complete line boundary map (including drafting time)			2/25/75 (1)		2/2/76 (2)			7/10/75 (3)		12/16/72(4)			
II 4	Classify features					1		2		3		4		
II 5-7	Scene verification						*1		2		3		4	
ADP 1-7	Scene preparation	1		*2	3	4								
ADP 8-17	Scene classification			1	2	3	4							
ADP 18-19	Scene verification using BEG Atlas and photos - Reclassification, if necessary						*1	2		3		4		
GLO	Analysis of GLO problems/interests in site 4								comparison (1)(2)		1,2,3		1,2,3,4	
II 8-10	Experimental verification (II and ADP evaluation steps identical (September-October)													
c/b	Cost-Savings Analysis (September-October)													

b) What is the "history" of ship channels as described on LANDSAT scenes? - including turbidity plumes from dredges, growth of spoil islands, estimated acreage of bay bottom and marsh or grassflat covered, vegetation appearing on spoil, changing land use on adjacent shores.

c) Have there been any changes in area or conditions of "wetlands" not related to dredging? seasonal changes? any trends" What impacts have the observed residential and industrial expansion had on Harbor Island area? Can expansion of these uses be related to the number of applications for easements, leases and structure registrations in GLO?

4.0 SIGNIFICANT RESULTS

The image interpretation mapping techniques have been successfully applied to test site 5, an area with a semi-arid climate and consequently a very different coastal environment than the previously-studied test sites. As a result, the land cover/land use classification developed for this investigation required further modification. The system shown in Table 1 (Section 3.3.2) is applicable to the entire Texas coast and will be used during the remainder of this investigation.

A new program, HGROUP, added to the ADP classification schedule (Table 2, Section 3.5) provides a convenient method for examing the spectral similarity between classes. This capability greatly simplifies the task of combining 25-30 unsupervised subclasses into about 15 major classes that approximately correspond to the land use/land cover classification scheme.

5.0 PUBLICATIONS

A paper describing the techniques for mapping from standard LANDSAT film products, the land cover/land use classification and selected test site results has been submitted to the Gulf Coast Section of the Society of Economic Paleontologists and Mineralogists. The paper will be published in October, 1976, at which time an oral presentation will be made. The content of the paper, which is entitled "Interpretation of Unenhanced LANDSAT Imagery for Wetland and Land Use Delineation in the Texas Coastal Zone" by Robert J. Finley, has been covered in this and previous quarterly progress reports.

6.0 RECOMMENDATIONS

None

7.0 FUNDS EXPENDED

GENERAL LAND OFFICE (GLO)

Labor	$4,606.00
Overhead	40.16
Travel	160.00
TOTAL EXPENDITURES REIMBURSED DURING THE 4th QUARTER	$4,806.16

BUREAU OF ECONOMIC GEOLOGY (BEG)

TOTAL EXPENDITURES REIMBURSED DURING THE 4th QUARTER	$ 0

TEXAS PARKS AND WILDLIFE DEPARTMENT (TPWD)

TOTAL EXPENDITURES REIMBURSED DURING THE 4th QUARTER	$ 0

TEXAS WATER DEVELOPMENT BOARD (TWDB)

Labor	$4,233.00
Computer	600.00
TOTAL EXPENDITURES REIMBURSED DURING THE 4th QUARTER	$4,833.00

CONSULTANTS

Dr. Holz	$2,250.00
Dr. Schell	436.96
TOTAL EXPENDITURES REIMBURSED DURING THE 4th QUARTER	$2,686.96

CUMMULATIVE TOTAL EXPENDITURES REIMBURSED DURING THE 4th QUARTER....................$12,326.12

8.0 DATA USE AS OF MAY 31, 1976

	IMAGERY Account #23790 Amount	CCT Account #G B3790 Amount	AIRCRAFT Account #G W3790 Amount
Value of Data Allowed	$2,900.00	$5,400.00	$9,588.00
Value Ordered	$1,482.00	$1,800.00	$9,564.00
Value Received	$1,460.00	$1,800.00	$9,564.00
BALANCE	$1,418.00	$3,600.00	$ 24.00

9.0 AIRCRAFT DATA

All NASA aircraft data flown for this investigation is now being used in a qualitative evaluation of map unit classification in sites 2, 3, and 5. The 1:40,000 color infrared photography of October 1975 (NASA Mission 325) has been used extensively because of its good clarity and large scale. Some of the individual units evaluated with NASA photography in sites 2 and 5 are those described in the discussion of image interpretation results (Section 3.2).

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APPENDIX A

LANDSAT COVERAGE OF THE TEST SITES 2, 3, 4, 5
FOR LANDSAT INVESTIGATION #23790

APPENDIX A

LANDSAT COVERAGE OF THE TEST SITES 2, 3, 4, 5

FOR LANDSAT INVESTIGATION #23790

ACQUISITION STATUS	SCENE ID	DATE	CLOUD COVER	QUALITY
	Test Site 2:			
	<u>Summer</u>: June - August			
2	1037 - 16251	08/29/72	20%	8888
	1343 - 16253	07/01/73	20%	8888
	1361 - 16252	07/19/73	20%	8888
2, 4	1703 - 16175	06/26/74	10%	8858
	<u>Fall</u>: Sept. - Nov.			
2	1073 - 16251	10/04/72	30%	8888
	<u>Winter</u>: Dec. - Feb.			
2	1217 - 16261	02/25/73	20%	8888
2	1505 - 16230	12/10/73	00%	2822
2	1901 - 16110	01/10/75	10%	8808
2, 4	2375 - 16112	02/01/76	00%	
2	1576 - 16152	02/19/74	00%	8888
	<u>Spring</u>: Mar. - May			
	1253 - 16262	04/02/73	20%	8888
2, 4	1289 - 16261	05/08/73	00%	8888
2	2051 - 16140	03/14/75	00%	8855
2	5027 - 16050	05/16/75	10%	5588

ACQUISITION STATUS	SCENE ID	DATE	CLOUD COVER	QUALITY
	Test Site 3:			
	Summer: June - Aug.			
	1343 - 16253	07/01/73	20%	8888
	1361 - 16252	07/19/73	20%	8888
	1038 - 16305	08/30/72	20%	8888
	1362 - 16305	08/30/72	20%	8888
2, 4	1703 - 16175	06/26/74	10%	8858
	Fall: Sept. - Nov.			
	1092 - 16312	10/23/72	20%	8888
	1110 - 16313	11/10/72	00%	8888
	1452 - 16291	10/18/73	00%	7828
	Winter: Dec. - Feb.			
2, 4	1146 - 16314	12/16/72	00%	8888
	1164 - 16312	01/03/73	10%	8888
	1182 - 16313	01/21/73	00%	8888
2, 4	2034 - 16200	02/25/75	00%	8888
	2016 - 16200	02/07/75	10%	5888
2	1578 - 16264	02/21/74	10%	8282
	Spring: Mar. - May			
	1253 - 16262	04/02/73	20%	8888
	1289 - 16261	05/08/73	00%	8888
	1236 - 16320	03/16/73	10%	8888

ACQUISITION STATUS	SCENE ID	DATE	CLOUD COVER	QUALITY
	1290 - 16315	05/09/73	00%	8888
	1308 - 16314	05/27/73	20%	8888
2, 4	1614 - 16261	03/29/74	10%	8888
	1974 - 16133	03/24/75	00%	8858
2	5028 - 16104	05/17/75	10%	8885
	Test Site 4:			
	Summer: June - Aug.			
2	1326 - 16315	06/14/73	10%	8888
2	1740 - 16225	08/02/74	20%	8888
	1758 - 16221	08/20/74	20%	8888
2, 4	5082 - 16080	07/10/75	10%	8888
	Fall: Sept. - Nov.			
2	1092 - 16314	10/23/72	10%	8888
	1110 - 16320	11/10/72	10%	8888
	1452 - 16293	10/18/73	10%	8828
2	2268 - 16184	10/17/75	00%	5555
	Winter: Dec. - Feb.			
2, 4	1146 - 16320	12/16/72	20%	8888
	1164 - 16315	01/03/73	20%	8888
2, 3*	1182 - 16315	01/21/73	00%	8888
	2016 - 16202	02/07/75	00%	5885
2, 4	2034 - 16202	02/25/75	00%	8888
2, 4	2376 - 16172	02/02/76		

ACQUISITION STATUS	SCENE ID	DATE	CLOUD COVER	QUALITY
	Spring: Mar. - May			
	1236 - 16323	03/16/73	20%	8888
	1254 - 16323	04/03/73	10%	8888
	1290 - 16321	05/09/73	20%	8888
1	5334 - 15523	03/18/76		
2	1308 - 16320	05/27/73	10%	8888
2	1974 - 16135	03/24/75	10%	8858
	5028 - 16111	05/17/75	10%	5588
	Test Site 5:			
	Summer: June - Aug.			
	1362 - 16315	07/20/73	20%	8888
	1380 - 16314	08/07/73	20%	8888
	1722 - 16235	07/15/74	20%	8888
2, 4	1740 - 16231	08/02/74	10%	8888
2	1758 - 16223	08/20/74	10%	8888
	Fall: Sept. - Nov.			
2	1110 - 16322	11/10/72	10%	8888
2	1776 - 16215	09/07/74	20%	5855
	1452 - 16300	10/18/73	20%	8888
	Winter: Dec. - Feb.			
2, 4	1182 - 16322	01/21/73	00%	8888
	1506 - 16293	12/11/73	10%	8888
2, 4	2034 - 16205	02/25/75	00%	8888

ACQUISITION STATUS	SCENE ID	DATE	CLOUD COVER	QUALITY
	Spring: Mar. - May			
	1614 - 16270	03/29/74	20%	8888
	1974 - 16142	03/24/75	10%	8888
	2070 - 16203	04/02/75	20%	8588
2	1290 - 16324	05/09/73	20%	8888

ACQUISITION STATUS

1 Imagery on Order

2 Imagery on Hand

3 Tapes on Order

4 Tapes on Hand

* Tape could not be reproduced by EDC/Goddard

APPENDIX B

PROGRAM HGROUP

```
DB0200-02*ELLTAB.HGROUP
C           PROGRAM HGROUP
C
C     HIERARCHICAL PROFILE-GROUPING ANALYSIS.
C     PARAMETER CONTROL-CARD FIELDS.
C           COL 1-5. NUMBER OF VARIABLES (MAX = 54).
C           COL 6-10. NUMBER OF SUBJECTS (MAX = 54).
C           COL 11-15. LEVEL OF GROUPING TO BEGIN GROUP-MEMBERSHIP PRINTING.
C           COL 20. 1 = STANDARDIZE DATA ON EACH VARIABLE BEFORE GROUPING.
C           COL 25. 1 = TRANSPOSE DATA MATRIX IN ORDER TO GROUP VARIABLES.
C     FORMAT MUST SPECIFY AN ALPHANUMERIC SUBJECT-CODE FIELD, FOLLOWED BY
C           NV SCORE FIELDS. IF DATA MATRIX IS TRANSPOSED (COL 25 = 1),
C           GROUP-MEMBERSHIP CODES WILL BE SERIAL NUMBERS OF VARIABLES.
C     SUBPROGRAMS REQUIRED ARE SUMF AND CCDS.
C
            DIMENSION D(54,54), KG(54), W(54), KF(20)
            REAL*8 LC(54), KC(54)
            ND = 54
          5 CALL CCDS (KF, NV, NS, KP, KS, KT)
            T = NS
C READ ALL DATA CARDS AND STANDARDIZE COLUMNS (VARIABLES), IF
C OPTIONED
            DO 10 I=1,NS
         10 READ KF, KC(I), (D(I,J), J=1,NV)
            IF (KS .EQ. 0) GO TO 20
            DO 15 J=1,NV
            A = SUMF(D, J, NS, ND) / T
            S = SQRT(SUMF(D, J, -NS, ND) / T - A * A)
            DO 15 I=1,NS
         15 D(I,J) = (D(I,J) - A) / S
         20 IF (KT .EQ. 0) GO TO 30
C     TRANSPOSE DATA MATRIX, IF OPTIONED.
            N = MAX0(NS, NV)
            DO 25 I=1,N
            DO 25 J=1,N
            X = D(I,J)
            D(I,J) = D(J,I)
         25 D(J,I) = X
            NS = NV
            NV = T
C     CONVERT DATA MATRIX TO INITIAL MATRIX OF ERROR POTENTIALS.
         30 DO 45 I=1,NS
            DO 35 J=1,NV
         35 W(J) = D(I,J)
            DO 45 J=I,NS
            D(I,J) = 0.0
            DO 40 K=1,NV
         40 D(I,J) = D(I,J) + (D(J,K) - W(K))**2
         45 D(I,J) = D(I,J) / 2.0
            DO 55 I=1,NS
            DO 55 J=I,NS
         55 D(J,I) = 0.0
            NG=NS
C     INITIALIZE GROUP-MEMBERSHIP AND GROUP-N VECTORS.
            DO 60 I=1,NS
            KG(I)=I
         60 W(I)=1.0
```

```
C  LOCATE OPTIMAL COMBINATION, IF MORE THAN 2 GROUPS REMAIN.
   65 NG=NG-1
      IF (NG .EQ. 1) GO TO 5
      X=10.0**10
      DO 75 I=1,NS
      IF (KG(I) .NE. I) GO TO 75
      DO 70 J=I,NS
      IF (I .EQ. J .OR. KG(J) .NE. J) GO TO 70
      DX = D(I,J) - D(I,I) - D(J,J)
      IF (DX .GE. X) GO TO 70
      X=DX
      L=I
      M=J
   70 CONTINUE
   75 CONTINUE
      NL = W(L)
      NM = W(M)
      WRITE (6,80) NG, L, NL, M, NM, X
   80 FORMAT (/ I4, 25H GROUPS AFTER COMBINING G, I3,
     14H (N=, I3, 7H) AND G, I3, 4H (N=, I3, 10H), ERROR =,
     2 F16.6)
C  MODIFY GROUP-MEMBERSHIP AND GROUP-N VECTORS, AND ERROR
C  POTENIALS.
      WS = W(L) + W(M)
      X = D(L,M) * WS
      Y = D(L,L) * W(L) + D(M,M) * W(M)
      D(L,L) = D(L,M)
      DO 85 I=1,NS
      IF (KG(I) .EQ. M) KG(I) = L
   85 CONTINUE
      DO 95 I=1,NS
      IF (I .EQ. L .OR. KG(I) .NE. I) GO TO 95
      IF (I .GT. L) GO TO 90
      D(I,L) = (D(I,L) * (W(I) + W(L)) + D(I,M) * (W(I) + W(M))
     1+ X - Y - D(I,I) * W(I)) / (W(I) + WS)
      GO TO 95
   90 D(L,I) = (D(L,I) * (W(L) + W(I)) + (D(M,I) + D(I,M))
     1* (W(M) + W(I)) + X - Y - D(I,I) * W(I)) / (W(I) + WS)
   95 CONTINUE
      W(L) = WS
      IF (NG .GT. KP) GO TO 65
C  PRINT GROUP MEMBERSHIPS OF ALL OBJECTS, IF OPTIONED.
      DO 115 I=1,NS
      IF (KG(I) .NE. I) GO TO 115
      L=0
      DO 100 J=I,NS
      IF (KG(J) .NE. I) GO TO 100
      L = L + 1
      LC(L) = KC(J)
      IF (KT .EQ. 1) LC(L) = J
  100 CONTINUE
      IF (KT .EQ. 0) GO TO 102
      IF (KT .EQ. 1) GO TO 104
  104 WRITE (6,105) I, L, (LC(J), J=1,L)
  105 FORMAT (2H G, I3, 4H (N=, I3, 2H) , 25I4 / (14X, 25I4))
  102 WRITE (6,110) I, L, (LC(J), J=1,L)
  110 FORMAT (2H G, I3, 4H (N=, I3, 2H) , 15A7 / (14X, 15A7))
  115 CONTINUE
      GO TO 65
      END
```

DB0200-02*ELLTAB.NORMAL

```
      C***PROGRAM NORMAL
      C   THIS PROGRAM NORMALIZES A VECTOR ARRAY
      C
      C   NV = VECTOR DIMENSION
      C   NS = NUMBER OF SAMPLES
      C   KF = VARIABLE FORMAT FOR READING CLASS NAME AND DATA VECTOR
      C
            DIMENSION KF(20),KC(50),D(50,50),VMAX(50)
      C   READ PARAMETERS, FORMAT AND DATA ARRAY
            READ(5,100) NV,NS,KF
        100 FORMAT(2I5,/,20A4)
            DO 10 I=1,NS
         10 READ(5,KF) KC(I),(D(I,J),J=1,NV)
      C   FIND MAXIMUM VALUE FOR EACH VARIABLE
            DO 20 J=1,NV
            DO 20 I=1,NS
         20 VMAX(J)=AMAX1(VMAX(J),D(I,J))
      C   NORMALIZE THE VECTORS
            DO 30 J=1,NV
            DO 30 I=1,NS
         30 D(I,J)=D(I,J)/VMAX(J)
            DO 40 I=1,NS
         40 WRITE(1,KF) KC(I),(D(I,J),J=1,NV)
            WRITE(6,200)
        200 FORMAT(//,' NORMALIZATION COMPLETED',//)
            STOP
            END
```

@BRKPT PRINT$

DB0200-02*ELLTAB.SUMF

```
            FUNCTION SUMF (X, KK, NN, ND)
      C
      C  COMPUTES SUM X OR SUM X**2 FROM A VECTOR.
      C  X = ARRAY CONTAINING THE SCORES TO BE USED.
      C  KK = ROW OR COLUMN NUMBER IF X IS A MATRIX. SET = 1 IF X IS A VECTOR.
      C     IF KK IS POSITIVE AND NOT 1, IT IS A COLUMN VECTOR.
      C     IF KK IS NEGATIVE AND NOT 1, IT IS A ROW VECTOR.
      C  NN = NUMBER OF VALUES TO BE SUMMED. IF NEGATIVE, SUM X**2 COMPUTED.
      C  ND = NUMBER OF ROWS (OR ELEMENTS) DIMENSIONED FOR X IN THE
      C     CALLING PROGRAM.
      C
            DIMENSION X(54,1)
            SUMF = 0.0
            N = IABS(NN)
            K = IABS(KK)
            IF (NN) 5,55,10
          5 IF (KK) 15,55,25
         10 IF (KK) 35,55,45
         15 DO 20 I=1,N
         20 SUMF = SUMF + X(K,I)**2
            RETURN
         25 DO 30 I=1,N
         30 SUMF = SUMF + X(I,K)**2
            RETURN
         35 DO 40 I=1,N
         40 SUMF = SUMF + X(K,I)
            RETURN
         45 DO 50 I=1,N
         50 SUMF = SUMF + X(I,K)
         55 RETURN
            END
```

DB0200-02*ELLTAB.CCDS

```
      SUBROUTINE CCDS (KF, KI, KJ, KK, KL, KM)
C
C  READS AND PRINTS TITLE, PARAMETERS, AND FORMAT CONTROL CARDS.
C  KF = VECTOR HOLDING VARIABLE FORMAT ON RETURN.
C  KI, KJ, KL, KM = PARAMETER VALUES.
C  KH = TEMPORARY STORAGE WITHIN THIS ROUTINE.
C  BLANK TITLE CARD YIELDS STOP.
C
      DIMENSION KF(20), KH(20)
      READ (5,9) KH
    9 FORMAT (20A4)
      IF (KH(1) .EQ. KH(2)) STOP
      READ (5,10) KI, KJ, KK, KL, KM, KF
   10 FORMAT (5I5 / 20A4)
      WRITE (6,15) KH, KI, KJ, KK, KL, KM, KF
   150FORMAT (1H1, 20A4 // 11H PARAMETERS / 13H COL  1- 5 = , I5 /
     113H COL  6-10 = , I5 / 13H COL 11-15 = , I5 / 13H COL 16-20 = ,
     2I5 / 13H COL 21-25 = , I5 // 15H DATA FORMAT = , 20A4)
      RETURN
      END
```

@BRKPT PRINT$

APPENDIX C

PROGRAM EXTRACT

```
J80200*LANDSAT.EXTRACT
      C***PROGRAM EXTRACT
      C
      C    THIS PROGRAM EXTRACTS BOUNDARIES FROM LANDSAT CLASSIFICATION FILES
      C    UNIT 8 = REGISTERED MAP USED AS INPUT
      C    UNIT 15 = OUTPUT IGF BOUNDARY MAP
      C
            DIMENSION LINE1(4000),LINE2(4000),LPRT1(4000),LPRT2(4000)
            DATA IN,IOUT/8,15/,ID,NPTS,XINC/1,1,0.1/,ISAVE/0/
            YINC=-1./6.
            CALL SETADR(IOUT,1)
      C     CALL SETMRG(2,'M,66,00,00 . ')
      C***READ IN CONTROL POINTS
          5 READ(5,500,END=6,ERR=85) NROW,NCOL
        500 FORMAT ()
            X1=(NCOL-1)*XINC + XINC/2.
            Y1=(NROW-1)*YINC + YINC/2.
            WRITE(IOUT) ID,NPTS,X1,Y1
            ID=ID+1
            GO TO 5
          6 NPTS=2
      C***INITIALIZE ARRAYS
            DO 10 I=1,4000
            LPRT2(I)=6H
         10 LINE2(I)=6H
      C***READ FIRST CLASSIFIED LINE INTO CORE
            READ(IN,END=99,ERR=86) NPIX,(LINE2(I),I=1,NPIX)
            NROW=1
            IEND=NPIX-1
      C***LOCATE BOUNDARY POINTS IN THE FIRST LINE
            DO 20 I=1,IEND
            IF (LINE2(I)-LINE2(I+1)) 14,20,14
      C***EXTRACT BOUNDARIES
         14 X1=I*XINC
            Y1=(NROW-1)*YINC
            X2=I*XINC
            Y2=NROW*YINC
            LPRT2(I)=LINE2(I)
            LPRT2(I+1)=LINE2(I+1)
            WRITE(IOUT) ID,NPTS,X1,Y1,X2,Y2
            ID=ID+1
         20 CONTINUE
      C***SHIFT DATA, THEN PROCESS NEXT LINE
         30 DO 40 I=1,4000
            LPRT1(I)=LPRT2(I)
            LPRT2(I)=6H
            LINE1(I)=LINE2(I)
         40 LINE2(I)=6H
            READ(IN,END=99,ERR=86) NPIX,(LINE2(I),I=1,NPIX)
            NROW=NROW+1
      C***LOCATE BOUNDARY POINTS
            DO 50 I=1,NPIX
            IF (I.EQ.NPIX) GO TO 46
            IF (LINE2(I)-LINE2(I+1)) 44,46,44
      C***EXTRACT BOUNDARIES
         44 P1=I*XINC
            Y1=(NROW-1)*YINC
```

```
      P2=I*XINC
      Q2=NROW*YINC
      LPRT2(I)=LINE2(I)
      LPRT2(I+1)=LINE2(I+1)
      WRITE(IOUT) ID,NPTS,P1,Q1,P2,Q2
      ID=ID+1
C***CHECK FOR BOUNDARY POINTS WITH PREVIOUS LINE
   46 IF (LINE2(I)-LINE1(I)) 48,50,48
   48 LPRT1(I)=LINE1(I)
      LPRT2(I)=LINE2(I)
      IF (ISAVE.EQ.0) GO TO 150
C***SAVE NEW BOUNDARY LINE
      XX1=(I-1)*XINC
      YY1=(NROW-1)*YINC
      XX2=I*XINC
      YY2=(NROW-1)*YINC
C***IF THE END POINTS DON'T MATCH WRITE THE CHAIN
      IF (X2.EQ.XX1.AND.Y2.EQ.YY2) GO TO 145
      WRITE(IOUT) ID,NPTS,X1,Y1,X2,Y2
      ID=ID+1
      X1=XX1
      Y1=YY1
      X2=XX2
      Y2=YY2
      GO TO 50
C***TIE ADJACENT BOUNDARY CHAINS TOGETHER
  145 X2=XX2
      Y2=YY2
      GO TO 50
C***BEGIN A NEW CHAIN
  150 X1=(I-1)*XINC
      Y1=(NROW-1)*YINC
      X2=I*XINC
      Y2=(NROW-1)*YINC
      ISAVE=1
   50 CONTINUE
C***OUTPUT BOUNDARY ON LINE PRINTER, THEN GET NEXT LINE
      CALL MAP
      IF (ISAVE.EQ.0) GO TO 30
      WRITE(IOUT) ID,NPTS,X1,Y1,X2,Y2
      ID=ID+1
      ISAVE=0
      GO TO 30
C***ERROR READING CONTROL POINTS
   85 WRITE(6,101)
  101 FORMAT(' ERROR READING CONTROL POINTS')
      STOP
C***ERROR READING FILE
   86 WRITE(6,100)
  100 FORMAT(' ERROR READING CLASSIFICATION FILE')
      STOP
C***END OF FILE
   99 ENDFILE IOUT
      CALL MAP
      WRITE(6,199) ID
  199 FORMAT(///,I10,' CHAINS EXTRACTED')
      WRITE(6,200)
```

```
  200 FORMAT(/,' BOUNDARY EXTRACTION COMPLETED')
C     CALL SETMRG(2,'",66,06,03 , ')
      STOP
C***
C   OUTPUT BOUNDARY MAP ON LINE PRINTER
      SUBROUTINE MAP
      NLINE=NLINE+1
      LAST=MINO(NPIX,120)
      WRITE(31,300) NLINE,(LPRT1(I),I=1,LAST)
  300 FORMAT(1X,J4,1X,120A1)
      IF (NPIX.LT.121) GO TO 10
      LAST=MINO(NPIX,240)
      WRITE(32,300) NLINE,(LPRT1(I),I=121,LAST)
      IF (NPIX.LT.241) GO TO 10
      LAST=MINO(NPIX,360)
      WRITE(33,300) NLINE,(LPRT1(I),I=241,LAST)
      IF (NPIX.LT.361) GO TO 10
      LAST=MINO(NPIX,480)
      WRITE(34,300) NLINE,(LPRT1(I),I=361,LAST)
      IF (NPIX.LT.481) GO TO 10
      LAST=MINO(NPIX,600)
      WRITE(35,300) NLINE,(LPRT1(I),I=481,LAST)
      IF (NPIX.LT.601) GO TO 10
      LAST=MINO(NPIX,720)
   10 RETURN
      END
```

@BRKPT PRINT$